Question 1: [5 Marks]

Consider an inverter with the following characteristics,

$V_{LS} = 0.8V$, $V_{TW} = 0.1V$, $V_M = -1.6V$, $V_{NMH} = 0.35V$, and $V_{NML} = 0.35V$

Draw the voltage transfer curve for this inverter assuming the curve is piecewise linear. Please show all critical voltages on the drawing.

$V_{LS} = 0.8V$ $V_{TW} = 0.1V$ $V_M = -1.6V$ $V_{NMH} = 0.35V$ $V_{NML} = 0.35V$

$V_{LS} = V_{OH} - V_{OL} = 0.8V$ —— (1)

$V_{TW} = V_{IH} - V_{IL} = 0.1V$ —— (2)

For ideal inverter VTC

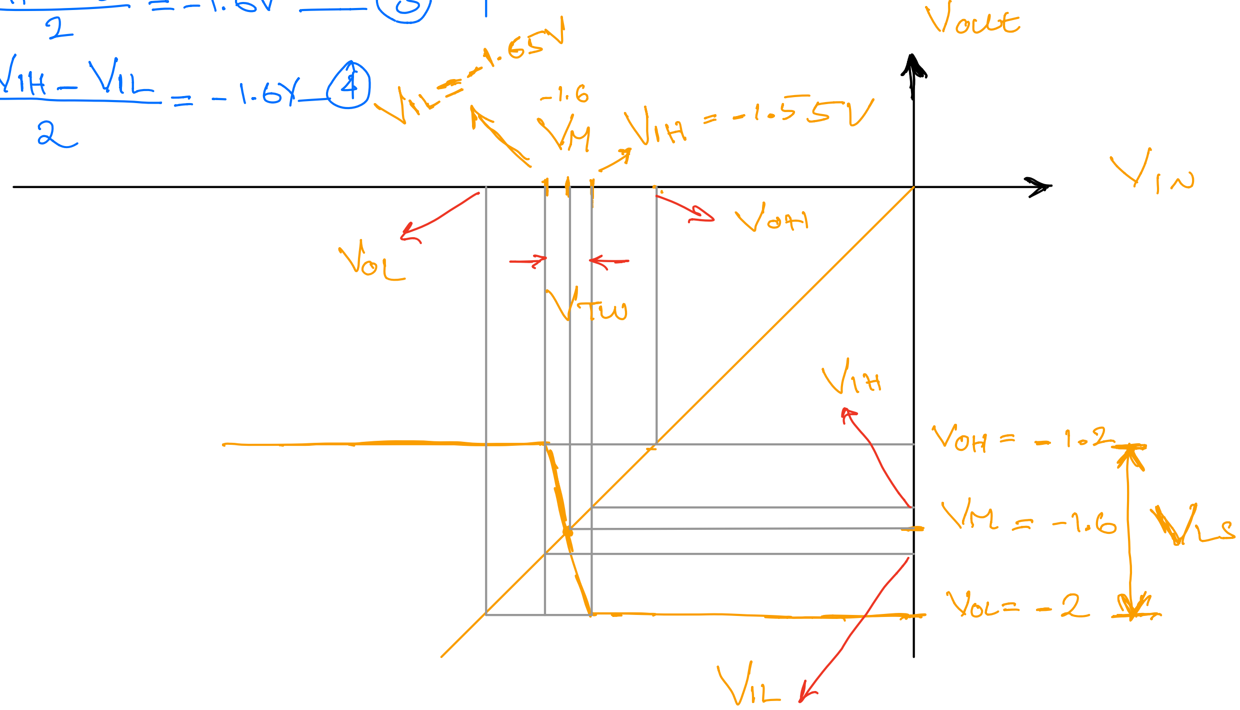
$V_M = \frac{V_{OH} - V_{OL}}{2} = -1.6V$ —— (3)

$V_M = \frac{V_{IH} - V_{IL}}{2} = -1.6V$ —— (4)

by solving (1) with (3) & (2) with (4)

$\boxed{V_{OH} = -1.2V}$ $\boxed{V_{OL} = -2V}$

$\boxed{V_{IH} = -1.55V}$ $\boxed{V_{IL} = -1.65V}$



Question 2: [5 Marks]

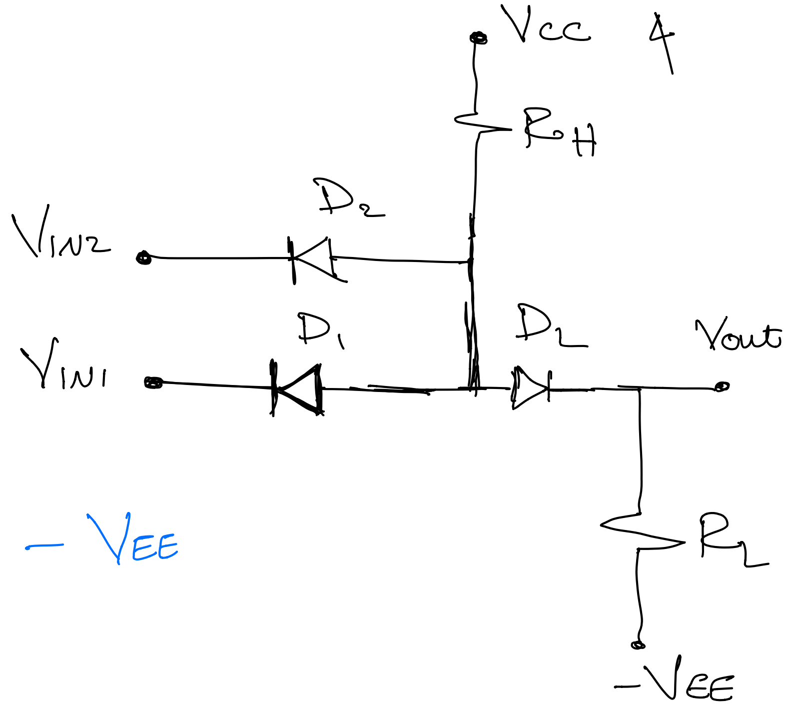
A. Draw cross section of a typical Schottky diode constructed on p-substrate and isolated with reverse biased junction.
B. Design a level shifted 2-input AND gate using only diodes and resistors. The gate must conform to the following specifications,

$V_{OH} = 0.87V$, $V_{OL} = -4V$, $P(OL) = 9.733mW$, $V_{CC} = 4V$, and $V_{EE} = -4V$

$V_{OH} = 0.87V$ $V_{OL} = -4V$ $P(OL) = 19.46mW$

$V_{CC} = 4V$ $V_{EE} = -4V$ → It should be $-V_{EE} = -4V$

To design means to find values of R_L & R_H



$$V_{OH} = IR_L - V_{EE}$$

$$I = \frac{V_{CC} - V_{D(ON)} + V_{EE}}{R_H + R_L}$$

$$V_{OH} = \left(\frac{V_{CC} - V_{D(ON)} + V_{EE}}{R_H + R_L}\right) R_L - V_{EE}$$

$$\frac{R_L}{R_H + R_L} = \frac{V_{OH} + V_{EE}}{V_{CC} - V_{D(ON)} + V_{EE}} = \frac{0.87 + 4}{4 - 0.7 + 4} = 0.667$$

$$\frac{R_L}{R_H + R_L} = 0.667 \quad \text{———} \quad (1)$$

$$V_{OH} = V_{CC} - IR_H - V_{D(ON)}$$

$$= V_{CC} - \left(\frac{V_{CC} - V_{D(ON)} + V_{EE}}{R_H + R_L}\right) R_H - V_{D(ON)}$$

$$\frac{R_H}{R_H + R_L} = \frac{V_{CC} - V_{D(ON)} - V_{OH}}{V_{CC} - V_{D(ON)} + V_{EE}} = \frac{4 - 0.7 - 0.87}{4 - 0.7 + 4} = 0.333$$

$$\frac{R_H}{R_H + R_L} = 0.333 \quad \text{———} \quad (2)$$

By dividing (1) by (2)

$$\frac{R_L}{R_H} = \frac{0.667}{0.333} = 2 \longrightarrow \boxed{R_L = 2R_H}$$

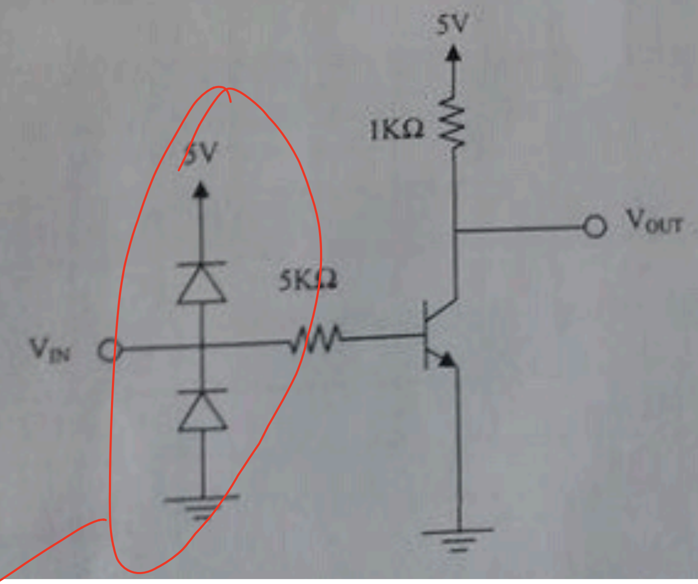
we can chose any values for R_L & R_H that as long as $R_L = 2R_H$

Consider the following RTL NOT gate. Assume $V_{BE}(SAT) = 0.8V$, $V_{CE}(SAT) = 0.2V$, and $\beta_F = 20$

Find the following.

a) Maximum fan-out

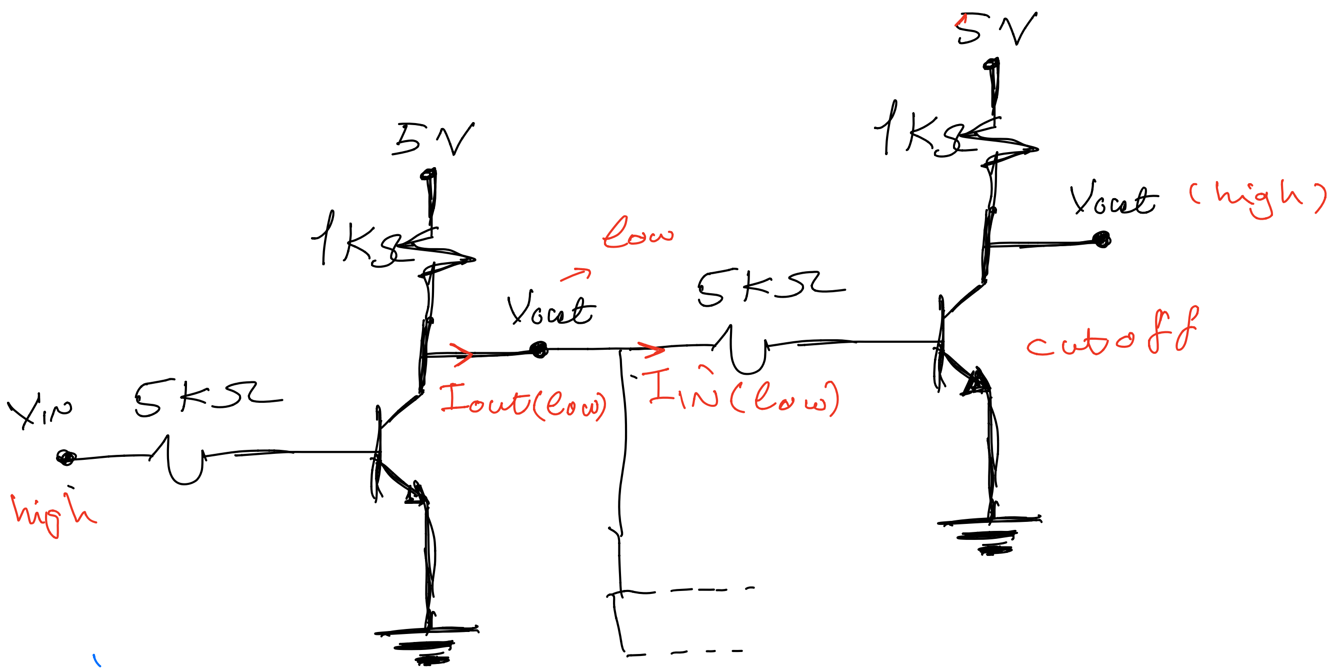
b) Average power dissipation with maximum fan-out



This part means V_{IN} range is $0 \leq V_{IN} \leq 5$

a

For V_{IN} is high V_{out} is low

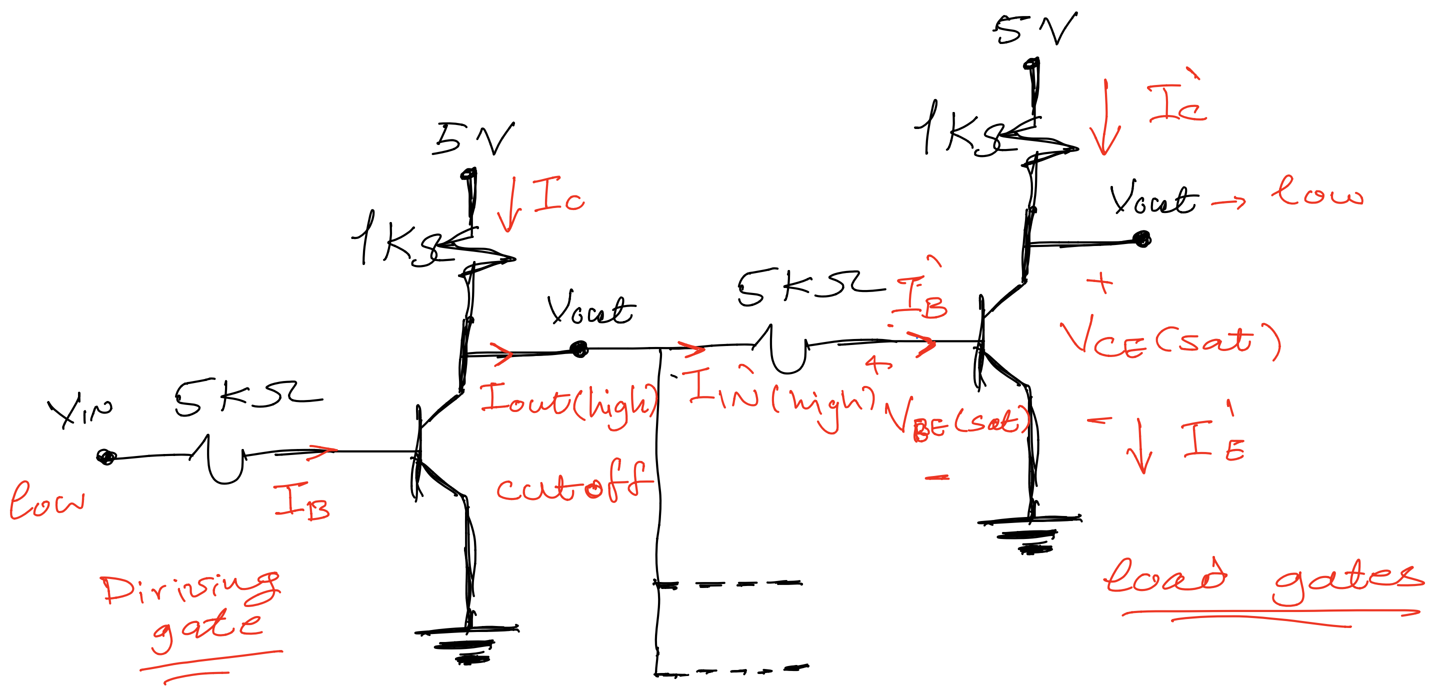


$I'_{IN}(low) = 0$

$$\Rightarrow N_{low} = \frac{I_{out}(low)}{I'_{IN}(low)} = \infty$$

Therefore The maximum fan-out depends on N_{high}

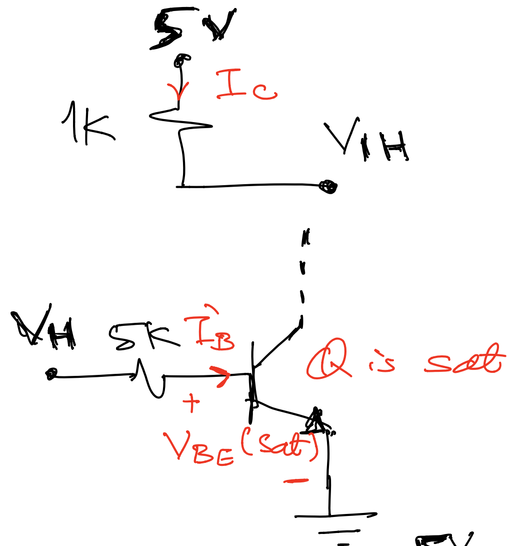
For V_{IN} is low V_{out} is high



$N_{max} = N_{high}(max)$

* The maximum fan-out can be found when the input for the load gates is the minimum input that can be considered as high input which is V_{IH}

$$N_{max} = \frac{I_{out}(high)}{I'_{IN}(high)}$$

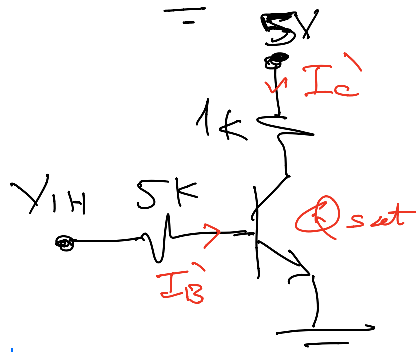


$$I_{out}(high) = I_c = \frac{5 - V_{IH}}{1K}$$

$$I'_{IN}(high) = I'_B = \frac{V_{IH} - V_{BE(sat)}}{5K}$$

$$V_{IH} = 5K \times I'_B + V'_{BE(sat)}$$

$$= 5K \times \frac{I'_c}{\beta_F} + V_{BE(sat)}$$



$$= \frac{5K}{\beta_F}\left(\frac{5 - V_{CE(sat)}}{1K}\right) + V_{BE(sat)}$$

$$V_{IH} = \frac{5K}{20}\left(\frac{5 - 0.2}{1K}\right) + 0.8 = 2V$$

$$I_{out}(high) = \frac{5-2}{1K} = 3mV$$

$$I_{in}(high) = \frac{2-0.8}{5K} = 0.24\,mA$$

$$N_{max} = \frac{3m}{0.24m} = 12.5$$

$\therefore$ The maximum fan-out is 12

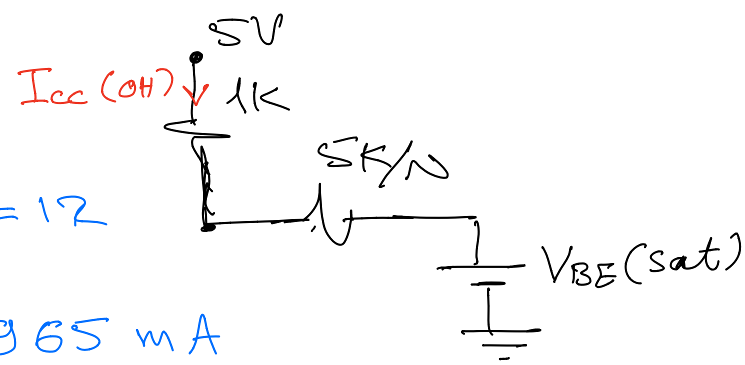
$\boxed{b}$

$$P_{cc}(avg) = \frac{P_{cc}(OH) + P_{cc}(OL)}{2}$$

$$= \left(\frac{I_{cc}(OH) + I_{cc}(OL)}{2}\right) V_{cc}$$

$$I_{cc}(OL) = I_c = \frac{5 - V_{CE}(sat)}{1K} = \frac{5-0.2}{1K} = 4.8\,mA$$

$$I_{cc}(OH) = \frac{5 - V_{BE}(sat)}{1K + \frac{5K}{N}}$$



The maximum fan-out $N = 12$

$$I_{cc}(OH) = \frac{5-0.8}{1K + \frac{5K}{12}} = 2.965\,mA$$

$$P_{cc}(avg) = \left(\frac{2.965m + 4.8m}{2}\right)(5) = 19.4\,mW$$